DOCUMENT RESUME

ED 098 151 SP 008 508

AUTHOR	Grobaker, Mark Randolph; Stull, G. Alan
TITLE	Thermal Applications as a Determiner of Joint Flexibility.
PUB DATE	[74]
NOTE	22p.; Paper presented at the Convention Research Section of the Kentucky State American Alliance of Health, Physical Education, and Recreation (1974)
EDRS PRICE	MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS	*Experiments; *Human Body; *Motor Reactions; *Temperature

ABSTRACT

This study investigates the relative effects of thermal applications of varying temperatures on the flexibility of specified joints. Subjects were 14 male college students ranging in age from 17 to 22 years with no previous joint injury or orthopedic disability. Each subject became familiar with the experimental design and was asked not to engage in any strenuous physical activity during the experiment. During the 8-week testing period, each subject reported at a prescribed time and was seated on a table for testing with the body and joints in a standardized position to evaluate the amount of joint motion. The test administrator measured ankle flexion and wrist flexibility and manipulated all movements while the subject remained as passive as possible. Experimental conditions consisted of cold and hot water treatments. To determine the effects of the varying temperatures, an analysis of variance was conducted on the change scores (post-immersion score minus pre-immersion score) using a 2x3 (temperature x time of immersion) factorial arrangement of treatment with repeated measures across both factors. Results indicate that cold water applications failed to affect range of joint motion at either the wrist or the ankle and that the range of motion at the wrist can be enhanced by immersion of the joint in hot water. (An 18-item bibliography is included.) (PD)

THERMAL APPLICATIONS AS A DETERMINER OF JOINT FLEXIBILITY

Mark Randolph Grobaker
Mount Washington County
School for Boys
Baltimore, Maryland

G. Alan Stull
Department of Health,
Physical Education, and Recreation
University of Kentucky
Lexington, Kentucky

Address for Proofs:
Dr. G. Alan Stull
101 Taylor Education Bldg.
University of Kentucky
Lexington, Kentucky 40506

Although immersion in either hot or cold water is a popular modality employed by coaches, athletic trainers, and physical therapists, the manner in which temperature influences joint flexibility has not been scrutinized with great care. As recently as 1969 Harris (9) noted the lack of literature on temperature and flexibility and wrote, "Only one source was located which studies the effects of varying temperatures on flexibility. Warm temperatures caused an increase in the range of movement, and cold temperatures caused a decrease." In agreement with this finding, Wright and Johns (18) reported a 10 to 20 percent increase in stiffness of the metacarpophalangeal joints when skin temperature was reduced to 18 degrees centigrade, and a decrease in stiffness when the temperature was raised to 45 degrees centigrade. More recently Sechrist and Stull (15) reported that following a 10-minute immersion in 10-degree centigrade water the range of motion at the wrist, elbow, or ankle was considerably less than that recorded following either a 10-minute immersion in 45-degree centigrade water, a 2-minute bout of mild activity, or a combination of the warm water immersion and mild activity.

Although there seems to be evidence that flexibility can be altered by thermal applications, the authors were unable to locate any studies which examined the effects of varying immersion periods on range of motion. Hence, the purpose of this investigation was to determine the relative effects of thermal applications of varying temperatures on the flexibility of specific joints. More specifically, this study attempted to reveal the relative effects of varying periods of immersion (10, 20, and 30 minutes) at varying temperatures (10 and 45 degrees centigrade) on range of motion at the wrist and ankle.

Method

Fourteen, male, college students, ranging in age from 17 to 22 years, volunteered to serve as subjects for this study. They were not paid for their services, and each reported that he had had no previous joint injury or orthopedic disability.

For testing, a protractor-arthrometer and supporting bench were positioned on top of a table, 203.20 cm. in length, 91.44 cm. in width, and 68.58 cm. in height. The semi-circular arthrometer, which recorded the range of joint flexion and extension of both the wrist and the ankle, was constructed of 12.70 mm. plywood and measured 154.94 cm. in length and 83.82 cm. in height. It assumed the appearance of an over-sized protractor with two large aluminum arms attached 12.70 cm. above the center of the base. The face of the arthrometer was graduated in degrees and covered a range of 195 degrees. The measuring arms, 72.39 cm. in length, 1.90 cm. in width, and 3.18 mm. in thickness, were used to record the range of movement. A small stand braced and elevated the arthrometer 33.02 cm. above the table top.

Two spring balances were utilized to regulate the amount of tension applied to the joint during testing. One, a Chatillon spring balance, had a steel "S" hook at one end and a closed steel ring at the other. Graduated in ounces with a maximum pull of 6 pounds (2.72 kg.), the cylinder-shaped balance allowed for a constant pull in measuring range of motion. A Welch spring balance with a maximum pull of 9.98 kg. was utilized for dorsiflexion (flexion) of the ankle.

A leather strapped masonite sandal was attached to a piece of masonite 6.35 mm. thick, 11.43 cm. in length, and 10.16 cm. in width. The strapped sandal was placed over the hand or foot to ensure proper alignment and to provide a site for attaching the "S" hook secured to the spring balance.

To brace and align the subject's hand and foot, a supporting bench was constructed of 12.70 mm. plywood. The bench, 33.02 cm. high, 30.48 cm. long, and 30.48 cm. in width, had 2 splices of rope looped over its top to hold the midline of the forearm and lower leg in place. Wooden slats, 12.70 mm. thick, were used to elevate the midline in a horizontal posture parallel to the stationary arm or the protractor arthrometer.

A 75.68-liter bucket was utilized to hold water during the administration of the thermal applications. This cylinder-shaped container was placed on the floor near the table so that the subject, while seated on the table, could insert his leg during the thermal application. Another bucket served as a water container for the wrist. This 18.92-liter receptable was positioned on the table next to the subject.

One week prior to the testing period, the subjects were given a brief orientation which included a demonstration. Each subject became familiar with the experimental design and was asked not to engage in any strenuous physical activity during the conduct of this investigation.

During the eight-week testing period, each subject reported at a prescribed time. Upon arrival to the laboratory, the subject was seated on the table for testing. At the start of the experiment it was necessary to standardize the position of the body and the specific joints in order to evaluate the amount of joint motion. Every effort to consider individual differences with regard to body height and leg length was made to comfort the subject's position. The preferred body positions were consistent with those recommended by Moore (13), Wiechec and Krusen (16) and the Committee on Medical Rating of Physical Impairment of the American Medical Association (5).

Logan and Dunkelberg (12) have stated that muscles on the opposite side of joints function reciprocally, and the muscles tend to resist stretching if relaxation is unable to take place. Hence, the test administrator manipulated all movements, and the subject was instructed to remain as passive as possible. Beetham (2) has reported that ranges of joint motion are rarely equal. He asserted that passive movements portray a greater amplitude of joint movement and tend to be a more reliable indicator of joint motion.

In order to assure a constant pull during the measurement of joint motion, the spring balance was attached to the subject's hand or foot and oriented at a 90-degree angle of pull from the point of attachment. Standardized postures for both the subject and tester were maintained throughout the experiment. Salter (14) has indicated that it is essential to standardize the posture of the body as well as positions of the joints on successive occasions. Thus, the same subject could be tested and retested at different times with consistent results.

The right ankle was randomly selected for initial measurement. The subject assumed a semi-reclining position on the table with the sagittal plane of the body parallel to the face of the protractor arthrometer. With the left leg extended and resting on the table, the subject was permitted to lean back and relax against a wall. The lower part of the right leg was elevated and placed on the supporting bench parallel to the instrument. The right knee was flexed at an angle of 120 degrees to overcome restrictions due to the action of the gastrocnemius (8). Slats of wood were placed under the supporting bench to elevate the lateral midline of the fibula even with the stationary arm of the protractor. The heel was positioned over the edge of the bench purposely to permit complete flexion (dorsiflexion) and extension (plantar flexion) of the ankle. For proper realignment of the leg after the experimental condition indelible ink was used to mark the point where the leg extended over the edge of the supporting bench. The two rope splices were employed to hold the leg in place on the supporting bench.

The tester sat directly in front of the protractor-arthrometer and made the necessary skeletal leg alignments with the aid of an assistant. The lateral aspect of the joint was used with the protractor facing anteriorly. The placement of the measurement arms was as follows: the stationary arm was positioned parallel to the lateral midline of the fibula on a line from the head of the fibula to the lateral malleolus, and the movable arm was aligned directly behind the strapped sandal which paralleled the lateral midline of the fifth metatarsal. At the zero-degree mark the foot was at a right angle with the midline of the lower leg. The region of the lateral malleolus was aligned with the protractor's fulcrum. No designated landmark was named as the center of the joint to coincide with the fulcrum on the protractor. Though much has been written about the axis of the joint, Moore's (13) work presents strong evidence to support the contention that there is no one specific bony landmark which could be called an axis of motion for complex movement of the wrist and ankle. According to Moore, to specify that the pivot of the protractor be centered on an anatomical landmark may falsify the motion actually present in the joint and open the results to criticism.

In measuring for ankle flexion the investigator pulled with his right hand on the Welch spring balance ich was secured to the strapped sandal, to a tension of 9.98 kg. The tester's left hand controlled the subject's movement through the uniaxial plane, and care was taken to avoid as much inversion and eversion as possible. At this time, the assistant tester marked a straight line on the protractor parallel to the strapped sandal. This procedure was standardized for all measurements in order to attain as much accuracy as possible (17).

With a constant force of 2.72 kg., the Chatillon spring balance was used to measure ankle extension. Again, the tester controlled the spring balance and uniaxial movement while alignment of the movable arm was accomplished by the assistant.

In the measurement for right wrist flexibility, the subject was in seated position with his back to the right front of the instrument. With the sagittal plane perpendicular to the protractor's face and elbow flexed, the subject extended his right forearm to rest in pronation on the supporting bench along a horizontal line. Beetham (2) and the American Academy of Orthopaedic Surgeons (7) have recommended that the forearm be pronated while measuring, since the relative degree of supination and pronation influences motion. The wooden slats were placed under the supporting bench when it was necessary to elevate the midline of the forearm parallel to the stationary measuring arm. To assure proper alignment the forearm was secured to the bench by means of two splices of rope which looped over top. So that the wrist could be aligned in the same position following the thermal application, the tester marked with indelible ink a line along the lateral midline of the forearm. Another marking was made on the ventral side of the forearm an inch below the ulnar styloid process where the forearm extended from the supporting bench. Dorinson and Wagner (6) have reported that measurements are more accurate if lines are drawn with a skin marking pencil so that the goniometer does not slip and can be replaced after the motion has been made.

The Chatillon spring balance was attached to the strapped sandal and used in both wrist flexion and wrist extension. With a constant pull of 2.72 kg., the test administrator manipulated the spring balance with one hand while controlling the uniaxial movement with the opposite hand. The stationary arm on the arthrometer was placed parallel to the lateral midline of the ulna toward the olecranon process. The movable arm was positioned parallel to the fifth metacarpal by the assistant.

One of the experimental conditions was a passive heat application which consisted of either a 10-, 20-, or 30-minute immersion of the joint in 45-degree centigrade water. The subject rested on the table with his right leg immersed in hot water directly beneath the table's edge, while resting the other on a chair. After 5 minutes, the arm was immersed in the 18.92-liter receptacle to the subject's immediate right. The elapsed time between the initiation of the leg and arm treatments enabled the administrator to record a post-immersion score for the ankle, while the arm remained submerged in the heated water. This procedure allowed the wrist to be tested immediately upon withdrawal.

During the experimental period the water temperature was maintained within plus or minus one degree centigrade by adding either hot water or ice. The thermometer was monitored at 60-second intervals. External conditions such as room temperature, which seldom fluctuated more than 1 or 2 degrees from 22 degrees centigrade, were standardized insofar as possible.

Following the experimental treatment, the subject dried himself, at which time the investigator quickly slipped on the strapped sandal. The subject was then instructed to assume the test position. This procedure was carried out for both ankle and wrist.

The experimental conditions for the cold water treatments comprised immersing the ankle and wrist in 10-degree centigrade water for periods of 10, 20, and 30 minutes. With the exception of the alteration in water temperature, the procedures employed for the cold water treatment were identical to the procedures used in the hot water treatment.

A pre-immersion score was derived from the arithmetic average of three readings for both joint flexion and joint extension taken prior to the thermal application. After the experimental condition, a post-immersion mean was obtained from the three readings. The difference between the pre-immersion and post-immersion means was taken as the change in range of movement induced by the respective experimental conditions.

In order to determine the effects of the varying temperatures on the range of joint motion an analysis of variance was conducted on the change scores (post-immersion score minus pre-immersion score) using a 2 X 3 (Temperature X Time of Immersion) factorial arrangement of treatments with repeated measures across both factors. For all tests of statistical significance, the .05 leve' of probability was employed.

Results

Table 1 shows that the 10-minute cold application caused a decrement of .19 degree whereas the 20-minute and 30-minute cold applications enhanced wrist flexibility by .63 and .30 degree, respectively. Table 2 indicates that for the heat treatment, all immersion periods seemed to enhance flexibility. The respective mean gains were 1.82 degrees for the 10-minute period, 1.56 degrees for 20 minutes, and 4.58 degrees for 30 minutes.

INSERT TABLES 1 AND 2 HERE

The results of the analysis of variance applied to the wrist flexibility changes are summarized in Table 3. It is observed that in the test for the main effects of time, the resulting F of 1.16 was not significant. This indicated that when averaged across both temperature levels, the varying immersion periods failed to differ in their effects on wrist flexibility. The F of 5.27 which resulted from the test for the main effects of temperature was significant at the .05 level. This revealed that when averaged across the three levels of immersion periods, the mean change of 2.65

Table 1

Descriptive Statisctics[a] for Cold Application for Wrist Flexibility

Periods of Immersion (Min.)	Test	$\bar{X}$	SD	$S_{\bar{X}}$	Difference
10	Pre	162.14	11.95	3.19	-.19
	Post	161.95	11.56	3.09	
20	Pre	163.31	12.28	3.28	+.63
	Post	163.94	10.62	2.84	
30	Pre	162.41	10.90	2.91	+.30
	Post	162.71	12.08	3.23	

[a]All figures presented in degrees.

Table 2

Descriptive Statistics[a] for Hot Application for Wrist Flexibility

Periods of Immersion (Min.)	Test	$\bar{X}$	SD	$s_{\bar{X}}$	Difference
10	Pre	163.94	10.78	2.88	+1.82
	Post	165.76	9.67	2.58	
20	Pre	166.71	12.71	3.40	+1.56
	Post	168.27	13.34	3.56	
30	Pre	161.92	11.67	3.12	+4.58
	Post	166.50	11.06	2.96	

[a]All figures presented in degrees.

degrees for the hot application was superior to the gain of .25 degree for the cold. The respective standard deviations for the main effects of heat and cold were 4.14 and 4.39 degrees. The final test was for the interaction between time and temperature, and this resulted in an *F* of 1.34 which was not statistically significant.

INSERT TABLE 3 HERE

Table 4 summarizes the descriptive statistics for the cold applications and reveals that for the ankle the mean decrements caused by the cold water applications were .78, 1.78, and 2.23 degrees for the 10-, 20-, and 30-minute periods, respectively. Table 5 presents the descriptive statistics for the hot application and reveals that in each case the heat tended to reduce range of motion. The observed decrements were .99 degree following the 10-minute hot application, 2.16 degrees after 20 minutes, and 3.24 degrees after 30 minutes.

INSERT TABLES 4 AND 5 HERE

A summary of the analysis of variance applied to the ankle flexibility results appears in Table 6. This table reveals that the test for the main effects of immersion time resulted in an *F* of 1.31 and the test for the main effects of temperature resulted in an *F* of 0.15, neither of

Table 3

Analysis of Variance Applied to Change Scores in Wrist Flexibility

	Source	DF	SS	MS	F
Time	A	2	42.09	21.05	1.16
	AS	26	474.36	18.22	
Temperature	B	1	121.68	121.68	5.27[a]
	BS	13	299.91	23.07	
Time/Temperature	AB	2	40.79	20.40	1.34
	ABS	26	394.29	15.16	

[a]Significant at .05 level.

Table 4

Descriptive Statistics[a] for Cold Application for Ankle Flexibility

Periods of Immersion (Min.)	Test	$\bar{X}$	SD	$S_{\bar{X}}$	Difference
10	Pre	64.75	9.82	2.63	-.78
	Post	63.97	9.96	2.66	
20	Pre	66.44	9.27	2.48	-1.78
	Post	64.66	10.63	2.84	
30	Pre	65.95	12.01	3.21	-2.23
	Post	63.72	10.61	2.84	

[a] All figures presented in degrees.

Table 5

Descriptive Statistics[a] for Hot Application for Ankle Flexibility

Periods of Immersion (Min.)	Test	$\bar{X}$	SD	$S_{\bar{X}}$	Difference
10	Pre	64.99	10.26	2.74	-.99
	Post	63.99	11.79	3.15	
20	Pre	71.85	11.34	3.03	-2.16
	Post	69.69	12.29	3.29	
30	Pre	65.85	12.57	3.36	-3.24
	Post	62.61	10.38	2.77	

[a]All figures presented in degrees.

which was sig .ficant. The test for the interaction between these variables yielded an F of 0.13 which was also not significant.

INSERT TABLE 6 HERE

Discussion

The results of this study failed to reveal any significant alteration in flexibility at either the wrist or ankle among the 10-, 20-, and 30-minute immersion periods. Furthermore, the lack of significant interaction at either joint suggested that there was no single optimal combination of time and temperature for altering range of motion. Hence, it would appear that any effect on flexibility elicited by either hot or cold water immersion occurs relatively rapidly (i.e., within 10-minutes), and any subsequent immersion beyond an initial 10-minute interval fails to cause any additional change in range of motion in a normal joint.

The only significant difference ($p < .05$) was that the application of hot water (45 degrees) was superior to cold water (10 degrees) for enhancing range of motion at the wrist. This finding was in accord with results of other investigators. Sechrist and Stull (15) reported that both passive (hot water application) and active (mild activity) warm-up elicited an increase in wrist flexibility whereas the cold application failed to cause any alteration. They further indicated that the application of heat coupled with mild activity produced an even

Table 6

Analysis of Variance Applied to Change Scores in Ankle Flexibility

	Source	DF	SS	MS	F
Time	A	2	34.56	17.28	1.31
	AS	26	342.53	13.17	
Temperature	B	1	1.95	1.95	.15
	BS	13	165.35	12.72	
Time/Temperature	AB	2	4.31	2.16	.13
	ABS	26	447.40	17.21	

greater range of motion at the wrist than did either treatment administered singly. In concurrence, Wright and Johns' (18) study on the effects of heat treatments and cold water immersion on flexibility of the metacarpophalangeal joints reported a 20 percent decrease in stiffness at 45 degrees centigrade. Similarly, Campbell (4) by applying hot packs as her heat treatment found an increase of 10 degrees during passive flexion measurements at the right hip. The present study did, however, fail to demonstrate any difference in ankle flexibility between the hot and cold treatments. This finding fails to support the results of Sechrist and Stull (15) who reported that at the ankle all forms of warm-up (passive, active, and a combination of the two) were superior to the cold water application, but that none of the warming techniques differed from any other. The reason for the discrepancy in these results is not immediately at hand although possibly the difference in tension placed on the ankle during measurement in the two studies may have been responsible. In the present investigation the actual tension on the ankle during flexion was 9.98 kg. and during extension 2.72 kg., whereas in Sechrist and Stull's study no attempt was made to standardize this procedure. It is possible that the results of the previous study would have differed had some more stringently controlled measuring procedure been used, and it also appears reasonable to hypothesize that had different amounts of tension been applied during testing in the present study a difference between temperatures may have been observed. Certainly additional research in this area would seem justified.

Most previous studies have either reported that joint motion is inhibited or unaffected by cold applications. Hence, the results of this study tend to agree with the prior research in that the cold water applications failed to affect range of joint motion at either the wrist or ankle. Studies by Hunter and Whillans (10), Le Blanc (11), and Campbell (4) have concluded that the application of cold tends to decrease or inhibit range of motion.

In summary, the only statistically significant result in the present study was that at the wrist, range of motion can be enhanced by immersion of the joint in hot water. There appears to be no advantage, however, in extending the time of immersion beyond 10 minutes.

References

1. American Academy of Orthopaedic Surgeons. Joint Motion: Method of Measuring and Recording, 1965.

2. Beetham, William P., Jr., Howard F. Polley, Charles H. Slocumb, and Walt F. Weaver. Physical Examination of the Joints. Philadelphia: W. B. Saunders Co., 1965.

3. Bierman, William, and Sidney Licht (ed.). Physical Medicine in General Practice. 3rd ed. New York: Paul B. Hoeber, Inc., 1952.

4. Campbell, Rose E. "A Study of Factors Affecting Flexibility." Unpublished Master's thesis, University of Wisconsin, 1955.

5. Committee on Medical Rating of Physical Impairment. "A Guide to the Evaluation of Permanent Impairment of the Extremities and Back," Journal of American Medical Association, 166: Special Edition, February 15, 1958.

6. Dorinson, S. M., and Margery L. Wagner. "An Exact Technic for Clinically Measuring and Recording Joint Motion," Archives of Physical Medicine, 29:468-475, August, 1948.

7. Downey, John A. "Physiological Effects of Heat and Cold," Physical Therapy Review, 44:713-717, August, 1964.

8. Fox, Fortescue R. "Demonstration of the Mensuration Apparatus in Use at the Red Cross Clinic for the Physical Treatment of Officers," Proceedings of the Royal Society of Medicine (Section on Balneology and Climatology), 10:63-68, March, 1917.

9. Harris, Margaret L. "Flexibility," Physical Therapy, 49:591-601, June, 1969.

10. Hunter, John, and M. G. Whillans. "A Study of the Effect of Cold on Joint Temperature and Mobility," Canadian Journal of Medical Sciences, 29:255-262, October, 1951.

11. LeBlanc, J. S. "Impairment of Manual Dexterity in the Cold," Journal of Applied Physiology, 9:62-64, July, 1956.

12. Logan, Gene A., and James G. Dunkelberg. Adaptations of Muscular Activity. Belmont, California: Wadsworth Publishing Co., 1964.

13. Moore, Margaret L. "The Measurement of Joint Motion--Part II: The Technique of Goniometry," Physical Therapy Review, 29:256-264, June, 1949.

14. Salter, Nancy, "Critical Review: Methods of Measurement of Muscle and Joint Function," Journal of Bone and Joint Surgery (British volume), 37-B:474-491, August, 1955.

15. Sechrist, William C., and G. Alan Stull. "Effects of Mild Activity, Heat Applications, and Cold Applications on Range of Joint Movement," American Corrective Therapy Journal, 23:120-123, July-August, 1969.

16. Wiechec, F. J., and F. H. Krusen. "A New Method of Joint Measurement and a Review of the Literature," American Journal of Surgery, 43:659-668, March, 1939.

17. Wilmer, H. A., and E. C. Elkins. "An Optical Goniometer for Observing Range of Motion of Joints," Archives of Physical Medicine, 28:695-705, November, 1947.

18. Wright, Verna, and Richard J. Johns. "Physical Factors Concerned with the Stiffness of Normal and Diseased Joints," Johns Hopkins Hospital Bulletin, 106:215-231, April, 1960.